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DOI:
10.1145/3012951

Educational Playgrounds: How Context-Aware Systems Enable Playful Coached Learning

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With edutainment and serious games, education has often been among the first domains to adopt new interaction paradigms. However, on the technology side, this domain remains conservative: education is not driven by technology but by people. Thus, apart from examples like Moodle, MOOCs and smartboards many potentials of HCI do not find their way into mainstream education. While we work on visions of smart homes, smart factories and even smart cities, the idea of "smart education" typically is associated with top-level educators rather than smart devices and augmentations. In this article, we present the vision of a context-aware system supporting educators and offering to students what we call "playful coached learning" (PCL).

Before going crazy about the scope of this vision, we have to limit its field of application. PCL is not going to help students to learn languages or teachers to rate essays; it focuses on practical, hands-on learning scenarios by augmenting physical work areas. This focus on physicality really changes the audience. Despite the rhetoric of participation, the majority of MOOC participants tend to be highly educated and higher socio-economic groups. However, looking at informal learning, it is clear there is a strong practical skills element in YouTube videos showing how to fold a photographic screen. PCL potentially opens up smart education to a wider group of people and tasks.

At the same time, PCL can improve the quality of academic and job-related education. Imagine a student in the STEM area, who has to learn how to a fit a circuit board or how to assemble a mechanical arm. In such exercise or lab scenarios, there typically will be a student / teacher relation of at least 10 to 1, often worse. This makes it hard for teachers to distribute their support adequately – as typically students with major problems will demand most attention while the ones doing okay or fine will receive little or no feedback. The user story (grey box on third page) illustrates how a PCL system would change this.

Technological Components – An Integration Task

On a technological level (Figure 1), PCL builds on a context-aware system. It creates a 3D representation of the working area and the user, especially hands, arms, and face. PCL recognizes the user's actions and triggers the multimodal and gamified presentation of hints and instructions, typically by in situ projection, tangibles, and audio. Based on the (ideally automatic) identification of the user, the system assesses a history of learning and skill development to detect changes and adapt the individual difficulty or guidance level.

Several of these components are in use for some time already, e.g. in-situ projection [3]. Even the combination of the core technological components like depth sensors, cameras and projectors has been prototypically realized in other domains, e.g. for assembly processes in production [2], or in the health domain for surgery [4] and for rehabilitation [1].

Pedagogic Effects: Self-Correcting Materials and Early Feedback

One of the aims of Montessori education is to have "self-correcting materials", e.g. stacking blocks so that the child knows when things have fitted properly, without a teacher saying so. A similar strategy called Poka-yoke (Japanese for "mistake-proofing") is applied in engineering to make physical work processes more intuitive. Amongst other things, this approach generates two critical pedagogic effects:

Autonomy and Reduced External Judgement. A teacher identifying errors, however helpful, can be experienced as stressful; the feedback shifts the focus to external motivation (satisfying the teacher) rather than internal (getting it right). In some ways, PCL is an automatic coach. As it will be designed with a transparent and simple feedback mechanism, the interventions are much closer to the physical activity and generate less distraction.

Early Error Detection. For many tasks, one is only aware that something went wrong well after the event causing the problem: for an electronic circuit when you turn it on, for route finding when you are lost... This late error detection causes frustration (extra effort) and requires complex diagnosis (where did I go wrong). However, most damaging is the "practiced" erroneous behavior. In contrast, PCL will feature a "stealth-mode" which intervenes when errors are about to be made and, depending on this user's level of guidance, offers potential solutions. For physical work, this is essential: physical actions are learnt tacitly, so erroneous physical training is hard to unlearn. In addition, the stealth mode reduces stress (a barrier to learning) as well as it reduces the perceived risk: the "what if I mess it all up?" feeling, blocking creativity and self-learning.

Figure 1. Vision of A user / student working with the PCL system. The technical setup is briefly described in the box below.

User / Student. Assessment of facial expressions (video camera) and potentially eye gaze (eye tracker). In the design phase, we will additionally track brain activity and skin conductance. The aim is to determine if the user is fatigued, stressed or distracted and eventually how motivated and happy he or she is.

Artefacts / Work pieces / Tangibles. Assessment of task progress and performance: how much has the student done and how well? We will assess objects profiles (using depth cameras, potentially stereoscopic cameras and object recognition) to detect if physical tasks are performed correctly. In addition, tangible objects are used which will serve as projection areas, containing e.g. guidelines or help videos.

Tools and Actions. Assessment of body and especially of hand movements (depth camera) to predict what the user will be doing. This is required for the early error detection (and the stealth mode). Before the soldering iron makes an error permanent, cautious feedback prevents irreversible "expensive" mistakes. Analyzing tremor and manner of movement could also supplement the facial analysis. In addition, by measuring movement paths and task completion times, PCL might be able to assess the user's skillfulness: tentative or clumsy versus confident and fluid movements.

From Playful Education to Emotion-Aware Coaching

Playful approaches in learning are not new at all: they are at the core of pedagogy. Accordingly, learning and playing have always been interwoven, often struggling for dominance. While playful design or gamification are methods to re-join them, the resulting solutions often do not incorporate the user's freedom of will – a quality philosophers like Suits deem essential for play [6]. Without the feeling of having a choice, playful education can create aversions: while it is okay to be obligated to learn or to work, nobody wants to forced to play. If a system becomes "aware" of the user's real-world interactions, this does not solve the problem of free will – but it strongly contributes to the user's sense of interaction and exchange, which in turn make his or her actions meaningful and raise the motivation to engage in potentially tedious processes like studying.

However, there is more to learning than the user's interactions with artefacts. PCL envisions reaching the competence of a dedicated teacher (with enough time for the students). Thus, it is not enough to add gamification elements like badges, levels and achievements. Neither does it suffice to know the learning history and be aware of current actions – we think that a good coach must also consider a student's emotions. While gamification and playful design help to raise the overall mood and motivation, this remains a one-way street unless a system can interpret emotional cues.

We think that in educational settings, only facial expression analysis will be accepted for gaining these cues. Even for this feature, the emotion analysis will need to be "black boxed", i.e. emotion records are neither accessible nor saved after a learning session. However, during the research and design phase of the PCL system we plan to use bio signals like galvanic skin response (GSR) or encephalography (EEG) as additional data sources [5]. While the aim is that the emotional cues from these invasive data sources and the non-invasive facial expression analysis converge, we are well aware that reliable emotion recognition is highly dependent on the advances in the field of affective computing. In this area, PCL will require most development effort in order to create a truly satisfactory user experience.

SUMMARY

PCL is good example of a combinatory innovation: most components are already "in place" – but they have not yet been combined and tailored to fit the field of education. We think that a system, which directly assists users in practical learning tasks, will help to increase the overall quality of education. Additionally, it will reduce stress for trainers and educators, generated by large groups and limited time resources. A motivating learning experience, incorporating emotional cues of the student, will help to raise the motivation for self-learning and contribute to practice and skill acquisition.

On the path towards PCL, we are happy to collaborate with researchers from the areas of education, affective computing, pattern recognition and machine learning. Therefore, if playful coached learning is something that might interest you or your students, do not hesitate to approach us.

PLAYFUL COACHED LEARNING: A USER STORY

Peter is a mechatronics trainee at a car manufacturer. He really likes his training but feels a bit lost in the practical exercises. His instructor often is in a hassle, firefighting the major problems in a group of 15 students. This situation changes, when prototypes of the new PCL-table are set-up. At the beginning, Peter is skeptical, that the odd apparatus with sensors and a projector will really help. Indeed, during the first session the system asks a few technical questions, projected on a white board the system asked him to place on the assembly grid. It is just a fancy multiple-choice app, he thinks.

However, this changes as the system asks if he is up for assembling a mechanical arm. Peter has tried this task once, but somehow the arm did not move correctly – it is a tough challenge. The projector then highlights the trays to pick parts from and the correct assembly locations. It even asks to turn the arm so it can "see" what Peter is doing. Sometimes, when Peter is uneasy or hesitates longer, it offers to show a video of the current process. In addition, after each action it comments, sometimes critical, mostly positive.

Once Peter just starts to solder a cable, when the system beeps loudly and projects a red cross directly onto his hand – he was in the process of using the wrong type of solder. After installing the third of four joints the system comments: "You can do better: You completed the first two joints in under 3 minutes each, and now you are taking more than 5 minutes." Of course, he then installed the fourth joint in under 3 minutes. The system reacts by displaying the "achievement: joint venture". While this reminds him of the games in his Steam library, he actually likes the continuous feedback, the scores and the measurements. The PCL system seems to "know" what he can do, trying to "challenge" and motivate him. When the instructor comes by to watch, he agrees: a job well done. Next time Peter will try to assemble the arm in the "stealth-mode", asking the system to offer no instructions and guidance but only intervene when errors are about to be made.

ENDNOTES

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